APPROACH TO REMEDIATION OF LANDSLIDE ON THE WORKING BENCH IN BUCIM OPEN PIT MINE

Kircho Minov, MSc.[1], Zoran Panov, DSc.[2], Radmila Karanakova Stefanovska, MSc.[3], Slobodan Stojanov, BSc.[4], Blagica Doneva, MSc.[5]
[1,4] "Bucim" DOOEL Radovis, Macedonia, email: kircominov@bucim.com.mk
[2,3,5] "Goce Delcev" University, Faculty of Natural and Technical Science, K. Misirkov bb, Stip, Macedonia, email: zoran.panov@ugd.edu.mk

ABSTRACT

Problems of (in) stability of slopes engineers meet every day. The instability of the slopes is a common occurrence on the surface pits and dump waste. Although, they are designed with allowable factor of safety, often sliding of the slopes occurs. Today, there are many new technologies for measurement and evaluation of the deformations of slopes, based on remote measurements and monitoring.
This paper presents the introducing of methods for geotechnical assessment that would reduce the occurrence of landslides.

Key words: approach, geotechnical assessment, slope stability, monitoring

1. Introduction

Current exploitation in the mine "Buchim" takes place in complex geotechnical conditions with appearance of crumbling, landslide and subsidence of the ground. This is especially manifest in recent months and is due to the deepening of the pit, rising to general working angle and primarily finishing angle. Contribution to this subsidence, occurrence of cracks and other deformities has the daily exploitation using mass blasting. The complexity of stability, especially in the past 4 - 5 months, with heavy snowfall and rain, further disrupt geotechnical stability especially in the northeastern and eastern part of the pit.

This disturbance causes a dangerous situation to workers, equipment and machinery. Most endangered building in eastern part of the central ore body (CRT) is the primary crushing. Although this building in construction - building character is founded on 40 meters in depth, and it was developed according to the technical norms for construction and operation, it is near the appeared crack, whose negative elements (subsidence, shifting and sliding) are expressed every day. From the above mentioned reasons, approaches to scientific and technical research on rehabilitation of the slopes of the northeastern part of the CRT of the mine "Buchim"- Radovish.

The objectives of this research are consistent with the essential requirements of the management of the investor. And that is the design of a complete system of exploitation for rehabilitation of landslide and other deformations in the eastern and northeastern part of the pit, then, determining the required margin of safety of slopes of the pit. Also, defining the technological processes of exploitation - drilling, blasting, loading, waste transportation and dumping.

2. Working and Finishing Slope on the Open Pit

General finishing angles on the designed open pit differ depending on the place where the normal cross section is taken for observation and same amount under the existing mining project [1]:

- On the places where transport paths don't cross final slopes, general angle is 45°.
- On the places where the transport path cuts the final slopes once, general angle is 42° 30'.
- On the places where the main transport spiral cuts the final slopes on two places, general angle is 40°.

General final angles of the projected surface mine, on the eastern part where expansion was done in order to repair the subsidence, depend on the place where the normal cross section is taken to observe and the same are:

- On the blocks in the area covered by the profiles B4 - B4' to B8 - B8', from the surface of the terrain to the relaxation on the bench 600, the general angle is 24°.

- On the blocks in the area covered by the profiles B4 - B4' to B8 - B8', from the surface of the terrain to the relaxation on the bench 450, the general angle is 36°.

2. Geometric Elements on the Open Pit

Based on made calculations, following geometric elements can be adopted on the open pit "Buchim", with special reference to the enlargement of the eastern part (table 1).

Table 1

Geometric elements on the open pit

No.	Geometric element	Sign	Value	Unit	Note
1.	Bench height	h	15	m	Whole open pit
2.	Bench width	s	7.5	m	Whole open pit
3.	Bench width	s_i	10	m	Benches 585,.., 465 in the enlargement in the eastern part
4.	Bench angle	α	63	°	Whole open pit
5.	Bench angle	α_i	56	°	Benches 585,.., 450 in the enlargement in the eastern part
6.	General finishing angle	β	45	°	Whole open pit
7.	General finishing angle	β_1	45.5	°	Whole open pit and cut one road
8.	General finishing angle	β_2	40	°	Whole open pit and cut two roads
9.	General finishing angle	β_{i1}	24	°	Benches 660,.., 600 in the enlargement in the eastern part
10.	General finishing angle	β_{i2}	36	°	Benches 660,.., 450 in the enlargement in the eastern part

3. Stability analysis of the open pit enlargement

One of the basic objectives of this paper is the analysis of the geotechnical stability of the open pit enlargement in the landslide part. Appeared cracks and subsidence and horizontal shifting of almost 2.8 m in direction West - East (monitoring March 2010 - March 2011), showed expressed geotechnical instability on this terrain and conditions for daily crumbling, subsidence and possible landslides. The folding on the pits floor (area within the profiles B4 - B4' to B6 - B6'), the bench 465, shows forming of slide plane.

Remediation and general stabilization of this slide area is possible to perform on the following four ways:

1. Unloading the mass from the surface - with the expansion of the final slope and decreasing of general angle of the open pit

2. Dumping of material on the lowest bench (E465) - in order to prevent further folding, sliding, adding load and stabilize the ground

3. Combination of the first two.

4. With special geotechnical methods - economically unacceptable for relatively large blocks and slopes

Analysis of previous experience and the modern research about the slopes stability of surface mines for similar geotechnical conditions imposed as the most rational and technically feasible is the first way for remediation and stabilization.

It doesn't mean that the second way is unacceptable. It would give the fastest and the cheapest results. The only dispute is the amount of unexploited reserves, which would remain "trapped" possibly with eventually dumping of the masses.

3.1. Geotechnical characteristics of the working medium

From the engineering - geological perspective and based on existing knowledge, the area of the deposit is characterized with "stable areas" with specific features of their stability.

For defining the slopes in terms of stability in the area of the deposit, some tests were carried out and obtained the appropriate physical - mechanical characteristics, which are used in the design of slopes of the open pit.

Narrow registered cracks are without filling, and those wider are filled with clayey and decomposed material. What is the fissuring in the field is expressed through the coefficient and module of fissuring.

Coefficient of fissuring means surface of cracks reduced to unit section of a typical part of the structure - texture zone. For quantitative evaluation of the frequency of occurrence of cracks and crack system is used to module of fissuring that represents the number of cracks of a one meter cross section of rock.

From the exploration in the deposit "Buchim" following values are obtained for the mention parameters:

Table 2.

Geomechanical parameters of the working medium

No.	Medium	Cohesion (planned condition) C [κPa]	Cohesion (current condition) C [κPa]	Angle of internal friction φ[°]	Volume weight γ [kN/m³]
1	Alternate gneiss (parallel to foliation) RMR = 37	150.00	≤30.00	33.54	26.20
2	Alternate gneiss (normal to foliation) RMR = 40	310.00	≤30.00	36.17	26.20
3	Andesite RMR = 54	2770.00	≤30.00	43.79	26.70
4	Fault zones RMR = 23	40.00	0.00	31.89	22.00
5	Cracks	0.00	0.00	31.89	22.00

4. Geotechnical Analysis of Slope Stability

Based on the analysis it could be concluded following assessment (table 3) of the stability for the current situation on the terrain in the open pit "Buchim" and new planned circumstances for rehabilitation of the eastern part of the pit.

Table 3

Geotechnical analysis of slope stability

No.	Profile	Current conditions in the open pit		Planned state with additional unloading (landslide remediation)		Condition for slope stability $F_{min}>1.3$	Comment
		Critical assumed sliding surfaces	F_{min}	Critical assumed sliding surfaces	F_{min}		
1	B4-B4’	S-3 and S-4	0.891	S-1	1.302	YES	Satisfactory stability
2	B5-B5’	S-1 and S-2	0.966	S-2	1.303	YES	Satisfactory stability
3	B6-B6’	S-3 and S-2	0.995	S-1	1.304	YES	Good stability
4	B7-B7’	S-2, S-3 and S-1	0.899	S-1 and S-2	1.301	YES	Satisfactory stability
5	B8-B8’	S-2, S-1, S-3 and S-4	0.896	S-1	1.301	YES	Satisfactory stability

It could be concluded that the condition for slope stability for the planned situation is fulfilled with additional releasing in the landslide zone in the northeastern part of the CRT of the mine "Buchim". For all profiles and assumed sliding surfaces, Fmin ≥ 1.3.

5. Remediation of the Landslide on the Open Pit

Current exploration in the mine "Buchim" takes place in complex geotechnical conditions with appearance of crumbling, landslide and subsidence of the ground. This is especially manifest in recent months and is due to the deepening of the pit, rising to general working and primarily finishing angles. To this subsidence, occurrence of cracks and other deformities contribute to the daily exploitation using mass blasting. In the past 3 - 4 months, heavy snowfall and rain further disrupt geotechnical stability especially in the northeastern and eastern part of the pit.

This disturbances cause a dangerous conditions for workers, equipment and auxiliary machinery. Most endangered building in east central ore body (CRT) is the primary crushing. Although this building in construction - building character is founded on 40 meters in depth, and is made according to the technical norms for construction and operation, it is near the appeared crack, whose negative elements (subsidence, tilting and sliding), daily come to expression.

5.1. Basic procedures for landslide rehabilitation

Basic objective of this paper is to define the rehabilitation of the landslide and subsidence on the eastern and northeastern part of the open pit. For that purpose was made complete geotechnical analysis of the current situation (part 4). In the same part was given estimation and geotechnical analysis on the new planned conditions for rehabilitation of the eastern part of the open pit.

The analysis made in previous research [1], indicates that after enlargement of the northeastern part of mine will come to rehabilitation and stabilization of this part. For these reasons, the procedure required for its rehabilitation has already been designed and revised. So, in this paper is presented approach to complete design of rehabilitation of the landslide in the eastern part of the pit, or in the area covered by the profiles B4-B4', B5- B5', B6- B6', B7-B7' and B8-B8'.

According the above said it could be said that landslide rehabilitation in the eastern part will be in two phases:

- Phase I – excavation to bench 600 and quick stabilization of the terrain, and then
- Phase II – excavation to bench 465, with full implementation of the designed solutions.

The difference in the quantities needed for recovery between previous studies and these made in this paper, is about 1.26 million tons for Phase I (up to bench 600), or 21.2 million tons total weight to bench 465 (fully incorporated to the bench 450).

✓ For rehabilitation with phase I (up to bench 600) is need excavation of about 2.15 million tons of total mass

✓ For rehabilitation with phase II (up to bench 465) is need excavation of about 5.36 million tons of total mass.

5.2. Design and development of the pit at remedying

During the construction and restricting of the open pit, northeastern part of the CRT in mine "Buchim" as the main bases were used available situational maps, geological maps, as well as findings from the current exploitation of the existing open pit and other similar mines.

According to the current conditions of ongoing exploitation and advancement of working fronts of the pit, and the further dynamics of working fronts, using the accepted parameters of the working and final slopes of the pit and use of geological maps from the eastern and northeastern part of the CRT, delimitation and design of the remediation of the eastern part of the pit was done.

It should be noted that with expansion of the pit in the eastern part, or with the delimitation, the relevance of the existing crack and the subsidence in this part were taken in consideration. Restrictions on the expansion of the mine in the eastern part, for repairing the same are as follows:

- The primary crushing is too close to appeared crack,
- Horizontal shifting of the slide plane of 2.8 m,
- Occurrence of the elevation of the lowest bench (elevation 465).
- Daily shifting, vibration, subsidence, crumbling and other types of geotechnical deformations.
- Uncertainty in the work and danger for staff and equipment.
- Possibility of endangering the regular exploitation of the mine.

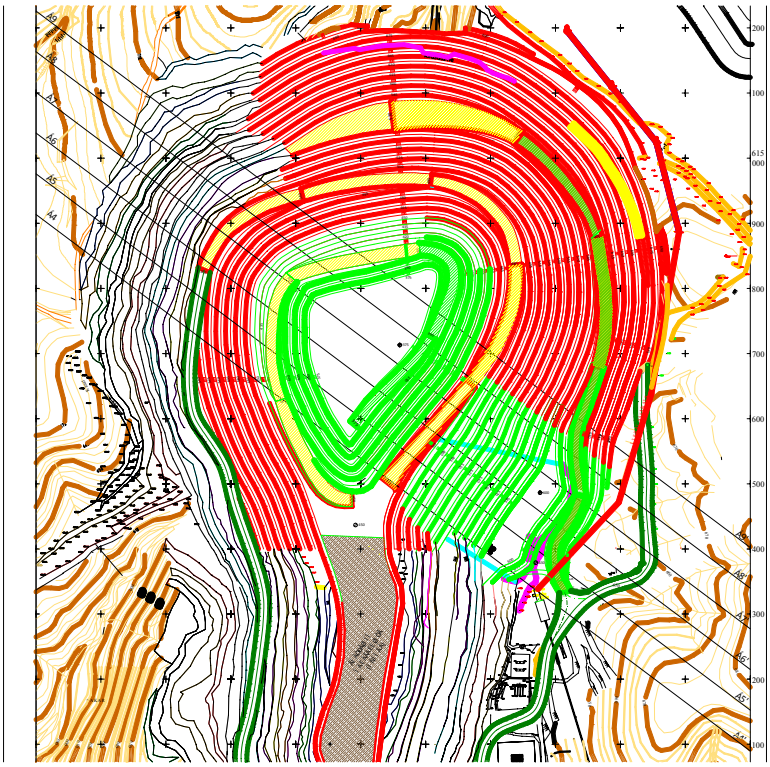

Fig. 1. Planned situation after remediation of the open pit (green)

Changes in design of the final benches are as follows:

- Expanding of the open pit in the eastern part for landslide rehabilitation. Expanding is in two phases.
- In Phase I is made expansion of the bench 600 for about 60 m (profile B7-B7'). Lowest value of the general angle is decreased from 39^{o} (according the existing mining project [1]) to 37^{o} (planned situation in this project, profile B7-B7').
- In Phase II is make construction of new benches with increased width of the working plane - width from 7.5 to 10.0 meters. Another decreasing of the general angle is present. In other words, on the same profile B7-B7', decreasing is from 43^{o} (according the existing mining project) to 34^{o} (planned situation in this project, profile B7-B7').

Other geometric constructive actions are the same and fit in all the procedures provided by the mining project [1].

There will be differences in the ways of opening and developing of the benches 660, 645, 630, 610 and 600 (Fig. 1).

6. Disscussion

Current exploration in the mine "Buchim" takes place in complex geotechnical conditions with appearance of crumbling, landslide and subsidence of the ground. This is especially manifest in recent months and is due to the deepening of the pit, rising to general working and primarily finishing angles. To this subsidence, occurrence of cracks and other deformities contribute to the daily exploitation using mass blasting. In the past 3 - 4 months, heavy snowfall and rain further disrupt geotechnical stability especially in the northeastern and eastern part of the pit.

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For assessment of the stability for remediation of the landslide, detailed geotechnical analysis on the profiles B4-B4', B5- B5', B6- B6', B7-B7' and B8-B8' was made. Also, engineering - geological mapping of the working benches covered by these profiles was done. Special attention was paid to the planned advancement of the excavation blocks in the next period. According the analysis could be concluded stability to the new planned area. Minimal safety factor is larger than 1.3 in all assumed slide planes.

Rehabilitation of the landslide in the northeastern part will be in two phases. In Phase I will be excavation up to bench 600 with fast stabilization of the terrain, and Phase II with excavation to bench 465 with full implementation of the designed solutions in the existing mining project [1]. The difference in the quantities needed for recovery between previous studies and these made in this paper, is about 1.26 million tons for Phase I (up to bench 600), or 2.16 million tons total weight.

7. Conclusion

General conclusions from investigations in this paper are:

- The paper gives complete solution for remediation of the northeastern part of the central ore body (CRT) of the open pit "Buchim",
- Results from the investigation are implemented in the existing mining project of the mine "Buchim",
- With the realization of the investigations, landslide will be remediate.

Some general recommendations of this survey are given below:

- Daily monitoring of the geotechnical condition of slopes stability of the excavation blocks (geodetic measurements, deformation measurements, strain conditions, mapping the terrain, etc.),
- Monthly control analyses for geotechnical stability,
- Possibility for formation of inner dumping place in the expanded part as alternative solution for terrain stabilization and decreasing of the expenses for transport and dumping of the waste,

- Final landslide remediation according the Phase I doesn't mean complete rehabilitation. The landslide will be complete remediate with implementation of Phase II. It means that after implementation of Phase I, analysis of the terrain stability should be made, and if there is not stabilization of the area, without delay to proceed with implementation of Phase II.

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